The economic potential of CT scanners for hardwood sawmills

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Abstract

Research has demonstrated that a knowledge of internal log defects prior to sawing could improve lumber value yields significantly. This study evaluated the potential economic returns from investments in computerized tomographic (CT) scanners to detect internal defects in hardwood logs at southern sawmills. The results indicate that such investments would be profitable for large mills in the region, even with only moderate increases in lumber value yields. For small mills, however, increases in lumber value yields would have to approach 30 percent for returns from an investment in this technology to reach an acceptable rate. Before the potential profitability of a CT scanner at midsize mills can be estimated, more precise information is needed on the cost of a complete scanning system, scanner performance in a mill environment and its effect on production, and the impact of use of a scanner on lumber grade yields.

Hardwood sawmill operators have been seeking ways to increase lumber value yields for some time. Attempts to accomplish this objective have included 1) developing ways to boost lumber recovery; and 2) increasing the proportion of high grades. Not only would these improvements raise mill profits, but society would benefit from enhancing the utilization of the hardwood resource. Increasing lumber value yields has become more important in the last 30 years, as the cost of logs has increased from 20 to 80 percent of total production costs (8).

Since the 1950s, numerous methods for increasing the volume of lumber produced per log have been studied. The research involved evaluating alternative systems that incorporate a knowledge of external indications of log defects and log geometry. The studies revealed that volume yields depend on both the method of sawing and the characteristics of the log. One investigation found that factoring taper and external defects into sawing decisions increased red oak lumber yields by as much as 9.4 percent for all logs and by 20.8 percent for grade No. 2 logs (9).

The orientation of a log on the carriage, with respect to the position and size of knots and other internal defects, can affect the yield of high lumber grades significantly. Recent efforts to improve the recovery of high grades from sawlogs have been focused on the application of a new technology for obtaining information on internal log defects. Of the several possible methods of internal log scanning, the two with the greatest promise are computer tomography (CT) and nuclear magnetic resonance (NMR). CT has been examined often for forest products applications and is likely to be the first method of internal defect detection employed at sawmills.

Our study of the economic feasibility of using internal defect scanners in sawmills focused on CT. While CT scanners are currently available for such industrial uses as testing poles and concrete, the scanning technology developed for medical use holds the most promise for adaptation to sawmills. Several researchers have reported on the effectiveness of these scanners for detecting internal log defects, indicating that this technology could be installed in sawmills. No information is available, however, on the economic impacts of employing the technology. The purpose of this study was to provide these estimates for hardwood

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sawmills in the South. The analysis considered a range of possible increases in the value of lumber produced at three size classes of mills.

Prior tomography research

Until recently, no nondestructive method of detecting internal log defects was available. Johansson (7) described NMR and CT scanners, the two internal scanning devices developed in the past decade that are being considered for use at sawmills. Both provide two-dimensional images of a cross-section of the scanned object. NMR, the newer method of internal scanning, is currently being evaluated for its applicability to sawmills. CT, however, is the type of internal scanning suggested most often for sawmill applications. Industrial applications of CT scanning include testing of concrete, steel, wood, and paper rolls (5,11,12,14). Also, CT is the most commonly employed form of internal scanning in medical diagnostics. The Automated Lumber Processing System (ALPS) for producing furniture parts more efficiently includes the use of CT scanning as a means of evaluating log defects in order to optimally position logs (10).

The first CT scanners, developed for medical use in the 1970s, paved the way for the application of the technology to industrial uses. In industrial CT scanners, x-ray tubes are replaced with radioactive isotopes. Although x-ray tubes would suffice as photon sources for medium-sized logs, they have the disadvantages of high cost and low penetrating power (14).

One of the initial investigations of CT's feasibility for sawmill use evaluated the technology's internal knot detection capabilities with sections of four southern pine logs and one red oak log (15). Each section was scanned at 16 separate planes and then sawn into 1-cm-thick cross sections corresponding to the tomographic planes. The images were then compared with the knots visible on the sawn cross sections. The overall results indicated that tomography provides an effective means of identifying internal defects, although the image analysis failed to identify all knots that could affect lumber grading.

Funt and Bryant (2) made a broader evaluation to determine CT's usefulness for identifying rot, holes, cracks, and clear wood as well as knots. They developed a computer algorithm to interpret the results. By employing color-coded images and shape tests, Funt and Bryant identified all defect categories in logs of varying moisture content.

Early CT scanners developed images by rotating the scanner around the logs to obtain scans from various positions. The centrifugal stress from rotations around such large objects prevents reduction of scan time to much less than one scan per second (16). At this speed, reliable images of a log's internal structure and geometry cannot be produced without markedly slowing log transfer rates.

New innovations in CT scanning, however, allow for significantly faster scanning times. Wagner et al. (16) described a CT design developed by Imatron, Inc., that allows scanning at the rate of 34 images per second. Rather than rotating around the object, the Imatron ultrafast model scans "a highly focused electron beam along semi-circular tungsten targets that partially surround the object." Thus, the tomograms are obtained without mechanical motion of the scanner or the log. A test of the scanner on a water oak log 15 inches in diameter and 12 feet long demonstrated that it could produce reliable images of sound and defective wood. Moreover, the results were obtained at a speed approximating actual sawmill production times. The software needed to translate CT scans into information for log positioning is not yet available. When developed, however, these programs will bypass the image phase and directly control the machinery for setting the log in position, or else mark each log indicating its optimum rotation.

Study methods

Since no CT scanner or other internal defect detection equipment is operating in a sawmill at present, its economic feasibility could not be studied directly. Therefore, the analysis of the technology's potential economic impact is based on several assumptions. These concern the magnitude of the increase in lumber value yield, the installation and operating costs of the scanner, and the effect of the scanner on sawmill production rates. Additional factors included in the analysis were mill size, tax level and depreciation schedule, discount rate, and scanner location within the mill.

To assure that the analysis was applicable to a wide range of circumstances, potential increases of 5 to 25 percent in lumber value yields were assumed for all mill sizes, and up to 35 percent for the smallest mill size. This enabled us to determine the minimum increases in lumber value yield necessary for CT scanners to be economically feasible for each size mill.

Installation costs were based on existing technology. Specifically, the costs used were for the ultrafast CT scanner developed by Imatron, as described by Wagner and others (6,16). This model was selected because the ultrafast technology is capable of analyzing logs at current log transfer rates, and Imatron engineers involved in sawmill CT research are acquainted with the modifications required to develop log scanners. The costs for the ultrafast CT scanner appear to be reasonable when applied to scanning logs. Ultrafast medical scanners are priced at between \$1.2 and \$1.5 million with service contracts amounting to approximately \$175,000 per year. Log scanners are expected to initially cost more to cover the expense of modifying the technology for sawmill use. Prices are likely to drop, however, as the scanners become more common in sawmills. The price of a log scanner may eventually be lower than that of a medical scanner, since detecting log defects requires less precision than medical diagnostics. Additional costs include those for developing software, similar to that of the Best Opening Face programs (8), and for a micro- or minicomputer to determine the optimal log orientations based on the log scans.

Two options exist for locating the scanner within a sawmill. The most obvious position would be immediately ahead of the headrig. With such a setup, the logs could be scanned, put in the optimal sawing position as determined by the computer, and held in that position for sawing. The scanner would be separated from the headrig by a surge bin to avoid the difficulty of synchronizing the two machines.

The second alternative is to place the scanner at the beginning of the milling process. Rather than mechanical-

TABLE 1. — *Annual value yield increases by mill size and increases in lumber value.*

Lumber value increase	Mill size		
	5 MMBF/year	10 MMBF/year	25 MMBF/year
(%)		———— ($) —	————
5		185,650	464,125
10		371,300	928,250
15		556,950	1,392,375
20		742,600	1,856,500
25		928,250	2,320,625
30		--[a]	--
35			

[a] 30 and 35 percent value increases were calculated for the smallest mill size only.

ly fixing the log's position, each log would be marked to indicate its optimal orientation, which would be set manually by the headrig operator before sawing. For several reasons, this second alternative was assumed in the analysis. Since most hardwood sawmills operate by manually positioning the logs, it would most likely be the initial setup for scanners. Furthermore, it would allow scanning to continue beyond normal mill operating hours and permit the scanner to service more than one headrig (13). Finally, such an arrangement would require a minimum of new equipment and little training to implement. An expenditure of no more than $100,000 would be required for additional equipment and training. An additional expense would be an annual overhead cost of $10,500 (6% of operating expenses) to cover the increase in working capital (4).

Three hardwood sawmill capacities were analyzed in order to evaluate the scanner's impact on profitability for different mill sizes. Capacities of 5, 10, and 25 million board feet (MMBF) per year represent the major mill-size classes encountered in the South. A study of sawmills in the Tennessee-Tombigbee Waterway region estimated that these three sizes constitute 18, 45, and 12 percent of the region's total hardwood sawmill capacity, respectively (1). While smaller mills abound, a capacity of 5 MMBF per year is probably the lower size limit for mills where a CT scanner would be economically feasible.

The lumber grade yields and prices used were based on existing information. Representative yields by grade were determined to be 12 percent FAS, 23 percent No. 1 Common, and 27 percent No. 2 Common. The remaining 38 percent was comprised of No. 3 Common and lower grades. These yields may be conservative, as some estimates indicate that No. 1 Common and better grades comprise 40 percent or more of total sawmill volume. However, they are similar to the results obtained by Hanks et al. (3) for most hardwood species, by averaging the lumber grade yields for each log grade. Lumber prices by grade were based on average prices reported in the *Weekly Hardwood Review* (17) for red oak. Prices per thousand board feet for FAS, No. 1 Common, No. 2 Common, and No. 3 Common and lower were $935, $505, $255, and $195, respectively. No real increase in hardwood lumber prices was considered since it is expected that prices will keep pace with inflation.

The maximum federal corporate income tax rate (excluding the 5% surtax) of 34 percent was employed in all after-tax calculations. State income tax was ignored because rates are generally quite low and vary considerably among states. The discount rate was set at 15 percent to approximate required returns on investments for most industries, especially where unfamiliar and untried investments are involved. Depreciation was calculated based on a 7-year asset using the modified accelerated cost recovery method permitted under the Tax Reform Act of 1986. Since the CT scanner technology would be categorized as a 7-year asset, all financial analyses were based on this time period.

The analysis was relatively straightforward using the values selected for the variables. Total daily income was estimated for each mill size based on the lumber grade yield percentages and prices. The daily income estimates were multiplied by 250 (operating days per year) to calculate annual income.

Study results

Estimates of annual total value yield increases for combinations of percentage value increases and mill size (Table 1) were obtained using the equation:

$$\text{Annual Value Increase} = \sum_{i=1}^{4} L_i P_i \times AV \times VYI$$

where:

L_i = percent of lumber grade i
P_i = price of lumber grade i
AV = mill size (annual output)
VYI = percent value yield increase

The first portion of the equation: $\sum_{i=1}^{4} L_i P_i \times AV$ provides an estimate of the gross annual income. The base values were $1.86, $3.71, and $9.28 million for the three mill sizes, from the smallest to the largest. The increase in gross annual income that could result from using a CT scanner was found by multiplying the base gross annual income for the mill by the assumed potential increase in lumber value yield (Table 1).

Several evaluation criteria are available for estimating the profitability of investments. The most common alternative is to calculate the net present value (NPV) of the investment. NPV is defined as the discounted value of expected returns minus the discounted value of the costs incurred in the investment, with both costs and returns being discounted at the same rate. An underlying assumption is that any intermediate returns will be reinvested at the interest rate used in discounting.

After-tax increases in annual income were calculated by first subtracting operating and overhead costs and depreciation from the increases in gross annual income attributable to the increased value yields. Next, this estimate of taxable income was reduced by 34 percent (the maximum federal corporate tax rate), leaving the residual income. Finally, the annual depreciation allowance was combined with the residual income estimate. Depreciation was added since it represents an accounting value that is allowed for determining taxable income. In those cases where annual expenses exceeded the annual income increases, the depreciation allowance minus excess expenses represented a tax saving.

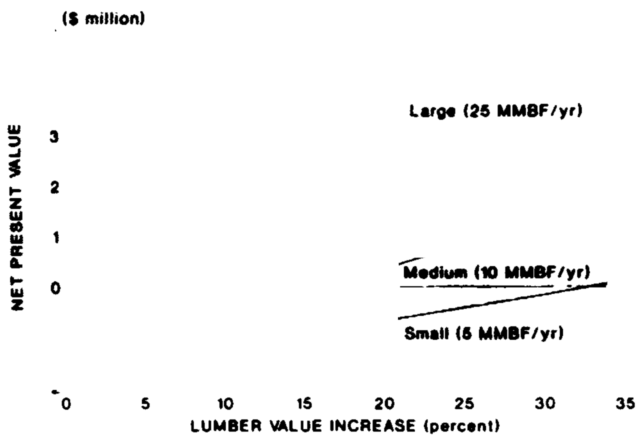

Figure 1. — Net present values for CT scanners, by mill size and increases in lumber value yield.

The after-tax increases in annual income were discounted at the rate of 15 percent to determine the present value of each annual increase. The discounted annual income increases were then summed for the 7-year period. The net present value of investing in the CT scanner was calculated by subtracting the initial investment of $1.5 million from the discounted 7-year income increases.

Based on a required return on investment of 15 percent, the CT scanner proved to be a profitable investment for mills in the 25 MMBF class even when the value yield increase was as low as 8.5 percent (Fig. 1). A value yield increase of 17.5 percent would result in the technology being profitable for 10 MMBF class mills. In contrast, the scanner would be economically feasible for the 5 MMBF mills only if the increase in value yield exceeded 30 percent. Differences in the profitability of scanners among mill sizes are indicated by the relative height of the curve for each mill size shown in Figure 1. Above these thresholds, the profitability increases at different rates for the various sizes of mills. Incremental increases in value yields raise the profitabilty of scanners substantially more for the largest mill size than for the two smaller sizes because the increases are spread over more lumber volume. The sensitivity of the technology's profitabilty to increases in value yield is indicated by the slopes of the curves.

Discussion and conclusions

This study determined that utilizing prior knowledge of internal log defects will increase lumber value, and therefore, investing in CT scanning equipment for some hardwood sawmills in the South is warranted. Research has already demonstrated that basing sawing decisions on a knowledge of internal log structure can increase lumber value yields significantly, and that CT scanners can detect the major classes of internal defects in logs.

More specifically, the study findings can be used as a guide to the sizes of sawmills where the technology could be applied profitably. The results indicate that the largest sawmills would profit most from the installation of CT scanners. Conversely, few, if any, small mills would be able to justify investments in such technology unless the anticipated value yield increases were extremely large or costs were very low. The profitability of CT scanners at moderate size mills is uncertain when value yield increases are in the middle range. For moderate size sawmills, the analysis indicated that CT scanners would be profitable with value yield increases of approximately 20 percent. More precise data on value yields, equipment costs, and production rates are needed, however, to adequately evaluate the justification for installing scanners at mills in this size class.

The most obvious deficiency in available data involves measuring the actual increases in lumber value yields provided by CT scanners. At present, economic analysts are forced to assume the most plausible value increases or to conduct a sensitivity analysis, as was done in this study. Value yield increases should relate to species, log size, and grade, since these factors influence lumber recovery and lumber grade distribution. Currently, it is not known how value yield increases vary by species. In contrast, it has been shown that value yield increases differ by log grade, with the largest increases occurring in No. 2 logs. Such results are logical, as the top quality logs contain few defects to affect lumber grades, while the lowest grade logs typically contain so many defects that little can be done to improve lumber grade yields.

A second area where information is lacking for economic investigations involves the physical application of the technology in operating sawmills. No sawmill is presently using a CT scanner because none are available that could be installed in a sawmill. Imatron's medical scanners, for example, cannot continuously scan logs larger than 15 inches in diameter (6).

Additional application problems include testing the capability of ultrafast scanners to operate at current log feed rates, and under actual mill conditions. Factors such as scanner downtime, required supervision, and the time required for processing scanned logs would influence production rates significantly. More definite information on the costs of the necessary computer hardware and software, training, and automated log-turning equipment must be known, as well as the effect that the location of the scanner has on costs.

CT scanning is a promising technology that warrants further research into its application. The widespread adoption of CT scanners could boost sawmill profits significantly, particularly at large mills, as well as provide benefits to society by conserving the South's hardwood sawtimber resource through improved utilization.

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